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Analysis of Grid Connected Rooftop Solar Pv-Building the Future of Clean Energy

Saumendra Behera [1], Vidyadhar[2]
[1]Assistant Professor, Department of Electronics and Communication Engineering, Gandhi Institute For Technology (GIFT), Bhubaneswar
[2]Assistant Professor, Department of Electronics and Communication Engineering, Gandhi Engineering College, Bhubaneswar

ABSTRACT
While the Jawaharlal Nehru National Solar Mission (JNNSM) opened up the solar electricity sector in India, the focus has primarily been on large-scale grid-connected power plants. With the drastic fall in prices of solar photovoltaic (PV) modules and balance of systems (BOS) Roof top PV(RTPV) systems can offer substantial benefits in terms of providing peaking supply of power, reducing T&D losses, improving tail end voltages, and creating local jobs. Roof top PV system is ideally suited for India, since it is socially equitable, economically viable, and environmentally sustainable (through the use of solar PV, a renewable resource in the grid-connected mode, thus avoiding the use of batteries). In this paper, we discuss the need for and advantages of emphasizing rooftop PV with net-metering as a self consumption power source in India, especially in large cities.

I. INRODUCTION

Renewable energy resources have attracted public, governmental, and academic attention due to the global energy crisis. An important technical challenge is the integration of renewable resources into the existing utility grid such that reliable power is injected without violating the grid codes and standards. There is an increasing focus on the development of solar energy in India for a variety of reasons, including our limited conventional energy reserves, their local environmental and social impacts, energy security, and climate change and energy access.

Rooftop PV (RTPV) systems are PV systems installed on rooftops of residential, commercial or industrial premises. The electricity generated from such systems could either be entirely fed into the grid at regulated feed-in-tariffs, or used for self consumption with the net-metering approach. A net-metering mechanism allows for a two-way flow of electricity wherein the consumer is billed only for the 'net' electricity (total consumption – own PV production) supplied by the DISCOM. Such RTPV systems could be installed with or without battery storage, and with one integrated net meter or two separate meters (one for export to grid and one for consumption).

SOLAR INDIA IN VISION OF JNNSM

The National Action Plan on Climate Change also points out: "India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy source. It also has the advantage of permitting the decentralized distribution of energy, thereby empowering people at the grassroots level". Based on this vision Jawaharlal Nehru National Solar Mission was launched under the brand name "Solar India".India is endowed with abundant solar energy, which is capable of producing 5,000 trillion kilowatts of clean energy. Country is blessed with around 300 sunny days in a year and solar insolation of 4-7 kWh per Sq. m per day. If this energy is harnessed efficiently, it can easily reduce our energy deficit scenario and that to with no carbon emission. Many States in India have already recognised and indentified solar energy potential and other are lined up to meet their growing energy needs with clean and everlasting solar energy. In near future Solar energy will have a huge role to play in meeting India's energy demand.

The Mission adopted a 3-phase approach, spanning the period of the 11th Planand first year of the 12th Plan (up to 2012-13) as Phase 1, the remaining 4 years of the 12th Plan (2013-17) as Phase 2 and the 13th Plan (2017-22) as Phase 3. At the end of each plan, and mid-term during the 12th and 13th Plans, there will be an evaluation of progress, review of capacity and targets for subsequent phases, based on emerging cost and technology trends, both domestic and global.

The selection of Solar PV projects of 500 MW capacity was decided to be undertaken in two batches over two financial years of Phase 1 i.e., 2010-2011 and 2011-2012. The size of PV projects in the first stage in 2010-11 was fixed at 5 MW per project. In batch-I, a total of 704 MW capacity grid connected solar power projects have been selected, which comprise of 500 MW capacity of solar thermal power projects and 204 MW of PV power projects. Phase I of JNNSM has been a success story with encouraging response from solar project developers. Under Batch II of Phase I, the total aggregate capacity of grid connected Solar Projects was 350 MW for the deployment of Solar PV Power Projects. Information as available from various developers indicate the following pattern of technology which will be adopted for setting up solar PV and solar thermal power projects of 802 MW capacity under JNNSM

PV'S ON BUILDINGS

For commercial buildings, the use of PVs may significantly influence the geometry, positioning and orientation of the building to maximize their viability.For domestic properties there is normally a part of the building, usually the roof that lends itself to the location of PVs. However, if the opportunity exists it is worththinking about the building design where it can be influenced to maximize thepotential of PVs wherever possible. This is especially true where solar thermal panelsare also being considered as there may be a limited amount of space suitable formounting the panels. PVs need to be considered as an integral part of the energy strategy of the buildingand of its functioning. The integration of PVs with the other building elements is critical to success, as ever appearance and aesthetics areespecially important.

The use of PVs should be part of the overall energy strategy for the building. Reasons to use PV include Energy costs, Environment, Security of supply, Demonstration / Education purposes, Architectural design / feature.
PVs are worth considering if the following key factors are right:

- Location: The solar radiation at the site is important and the building on the site needs to have good access to it.
- Demand: The PV installation should be sized so as to optimize (in practical and economic terms) the amount of electricity which can be contributed to the overall electrical demand, e.g. Storage or stand-alone system, grid-tied system.
- Design: PVs will affect the form and aesthetics - the community, the client and the designers all need to be satisfied with the result.

WHAT DIFFERENCE DO PVS MAKE TO A BUILDING?

The main points to address are:

- Orientation.
- Footprint.
- Facade.
- Section.

A building orientated to the south for delighting, passive solar gain and free of over shading iseminently suitable for PVs. Similarly, a footprint with the long axis running east-west thus giving alarge south-facing wall area and potentially a large south-facing roof is advantageous for PVs.The façade of a building is more complex.It is important to remember that PV can be wall mounted as well as roof mounted, but can still be verybeneficial in terms of contribution to the overall energy requirement of a building. A similarity can bedrawn to a window, which is a very simple "passive" element of a building, which provides free energygains to a building (heat and light).

Firstly, in construction terms, building-integrated PV systems need to play the same role as thetraditional wall and roofing cladding elements they replace. Consequently, they must address all thenormal issues, for example:

- Appearance.
- Weather tightness and protection from the elements.
- Wind loading.
- Lifetime of materials and risks and consequences of failure.
- Safety (construction, fire, electrical, etc.).
- Cost.

In addition, there are a number of more particular aspects, often associated with being able to use theElectricity produced, namely:

- Avoidance of self shading
- Heat generation and ventilation.
- Provision of accessible routes for connectors and cables
- Maintenance

GRID CONNECTED ROOF TOP SOLAR PV SYSTEM

In recent years solar PV systems became viable and attractive. Utility scaleplants are being set up worldwide with promotional mechanisms which are set up on ground surface. Available roof-top area on the buildings can also be used for setting up solar PV power plants, and thus dispensing with the requirement of free land area. The electricity generated from SPV systems can also be fed to the distribution or transmission grid after conditioning to suit grid integration.

The roof-top solar PV systems

- Area easy to install and maintain
- Have long life of 25 years

Grid-connected solar photovoltaic (PV) systems are expected to proliferate over the coming decade and higher penetration levels will put a premium on achieving optimal performance and reliability. A PV solar plant is a plant that uses solar cells to convert solar irradiation into electrical energy. PV solar plants consist of solar modules, an inverter converting DC into AC and transformer conveying the generated power into the grid net. PV solar plant is fully automated and monitored by the applicable software. It has been shown in practice that the energy efficiency of PV solar plant decreases from 0,5-1% annually. The real lifetime of silicon-made PV modules is expected to be at least 30 years.Since there are no moving parts in the system and it requires only minimal attention. But depending upon the dust level, the system requires periodic cleaning.

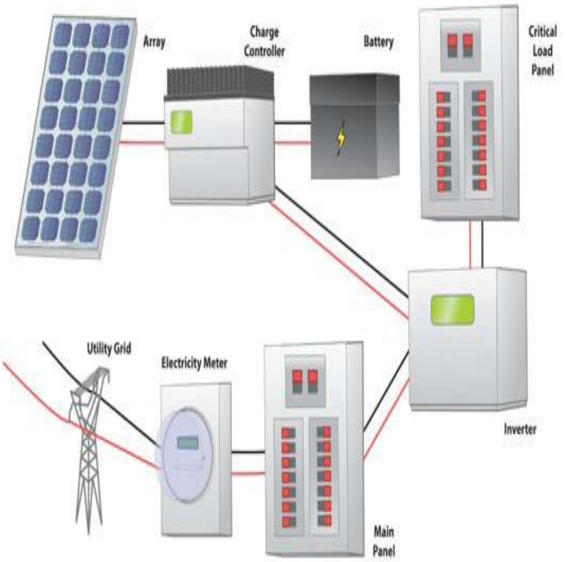


Fig. PV system connected to grid & battery

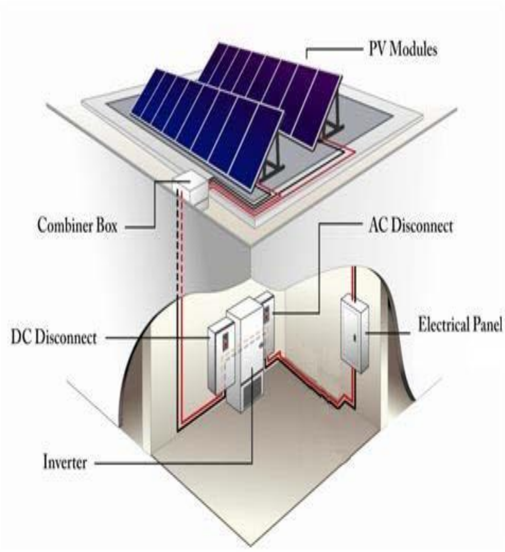


Fig.PV system components

ADVANTAGES:

The grid connected roof top solar PV system would fulfill the partial / full power needsof large scale buildings. The following are some of the benefits of roof top SPV systems:

- Generation of environmentally clean energy.
- Consumer becomes generator for his own electricity requirements.
- Reduction in electricity consumption from the grid.
- Reduction in diesel consumption wherever DG backup is provided.
- Feeding excess power to the grid.

IMPORTANT ISSUES:

a) Application:

The proposed generator shall submit the prescribed application to theconcerned DE/Opn along with registration fee of Rs.1000/- in the form ofDemand Draft in favour of concerned DE/Opn. The DE/Opn will arrangeacknowledgment for the same for the net metering as per the application billingperiod.

b) Standards of Solar PV panels:

The Solar PV panels proposed to be installed shall meet the requirements ofIndian as well as IEC standards. Further, the documentary evidence proving theprescribed standards has to be furnished by SPV generator to the concernedauthority (DE/Opn).

c) Metering:
0.2 class accuracy, tri-vector based energy meter, non ABT having the MRIdownloading facility along with related accessories shall have to be installed bythe SPV generator as per the specifications of APTransco / APDiscoms.The SPV generator shall bear the entire cost of metering arrangementprovided including its accessories.

d) Billing:
The SPV generator shall pay for the net energy in a billing month as perapplicable retail supply tariff decided by regulatory commission to theconcerned DISCOM, if the supplied energy by the licensee is more than theinjected energy by the solar PV sources of the consumer(s).Any excess/ surplus energy injected in to the grid in a billing month will betreated as inadvertent and no payment will be paid for such energy.Spot billing is to be arranged by concerned ADE/Opn as per the billingperiod. DISCOM shall arrange to develop suitable software and incorporate in thebilling instrument for such billing.

e) Protection:
The SPV generator is required to provide an appropriate protection system ontheir incoming side / consumer premises with the feature of "Islanding the SPVgenerator" when grid fails.Protection system including its switch gear has to be certified byconcerned DE/MRT.Further, harmonic suppressive device has to be installed by such SPVgenerator to suppress the harmonics injection as harmonics is more in case ofsolar plants where conversion of DC to AC is taking place.

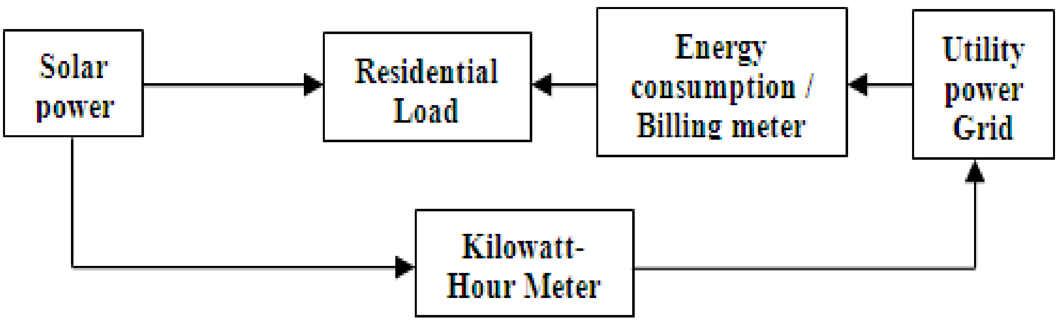
f) Statutory approvals:
The SPV generator needs to get statutory approvals from appropriate authority(CEIG) for the connected equipment including its solar panels.

g) Insurance:
In order to meet the connected protective and switch gear, the SPV generatoris required to provide an insurance coverage of Rs.5,00,000 per annum.

h) Technical feasibility and synchronisation:
The proposed generator shall submit the prescribed application to theconcerned DE/Opn.Concerned DE/Opn and DE/MRT will issue a technical feasibility certificateand witness the synchronization of SPV plant with distribution network.

NET METERING

Net metering and other solar policies encourage rooftop solar deployment and have made solar power generation a good deal for more than just the wealthy. It is important that these policies continue to be offered to accelerate the growth of rooftop solar across the country.Net metering is the concept which records net energy between export of generated energy and import of DISCOM energy for a billing month. Alternatively, the meter, having the feature of recording both the import and export values, besides other parameters notified by CEA metering regulations and TRANSCO / DISCOM procedures in vogue, shall also be allowed for arriving net energy for the billingperiod.



figSchematic diagram of building integrated grid connected pv system with net metering scheme

BIPVs have been increasingly incorporated into new buildings but constitute an effective alternative in case of retrofitting measures especially as far as building face lifting is concerned.In this system a solar photovoltaic (PV) plant owners can also enjoy the opportunity of net metering by selling energy to the National grid when the consumed energy is less than the De-livered energy. Here we use two meter for metering the consumed and delivered power. The energy consumption/billing meter will record how much energy is consumed by the costumer from the utility power grid. When the kilowatt-hour meter will record the amount of energy is delivered from the solar system to utility power grid.

ROOFTOP PV POLICY-A CASE FOR SUSTAINABLE DEVELOPMENT

The Indian power sector is facing multiple crises, ranging from financial viability of distribution utilities to the challenges in ensuring electricity for all while trying to reduce adverse local socio-environmental impacts. Such a scenario requires innovative policies which can help address more than one crisis. Promoting RTPV for self consumption is one such policy approach.

Equity: The suggested tariff approach would only require commercial outfits and households with high energy consumption owing to AC usage (consuming > 300 kWh/month) to either adopt RTPV or pay much higher tariff. This in turn would free up electricity generated from precious natural resources (i.e. coal-based thermal power) for the benefit of the needier populace, and thereby reduce shortages/load shedding. If consumers do not shift to RTPV, it could raise financial resources for utilities, thus enabling them to absorb the higher cost of fossil fuel based generation for consumers with lower tariffs. The higher incremental cost of RTPV electricity would not be passed on to all consumers, which will make the approach more equitable.

Economy: Net-metering is economically viable for consumers with high levels of energy usage and high avoided tariffs, and further provides cost certainty over the lifetime of the project. Additionally, it is well accepted that current fossil fuel based power is unsustainable, and in the long term, a shift to renewable sources is inevitable. Hence, the suggested approach essentially implies that high-end domestic and commercial consumers would have to pay a long-term marginal price for electricity. Such an approach based on a long-term marginal price is economically efficient as it forces consumers to pay the real cost of electricity, and would require consumers to use electricity more judiciously. Also, since the investment decisions will be made by the consumers, this will help avoid many 'governance' and 'agency' problems of the utility deciding on behalf of consumers. The net metering approach will also be economically efficient as it would not involve any subsidy from tax payers or rate payers.

Environment: Since RTPV is a renewable source of energy, does not require dedicated land, and saves on precious water use, it is an environmentally benign option. Further, with grid interconnection and banking facility, the use of batteries, which have significant environmental implications, is also avoided.

10 PREDICTIONS FOR ROOFTOP SOLAR POWER IN 2014

1. Net metering will win in big solar states and lose in small solar states. The efforts of SEIA, Vote Solar and others make a tremendous difference -- but the biggest factor is voters who want more solar. As such, states with a strong solar constituency (like California with almost 200,000 rooftop systems) will be most successful in passing solar-friendly policies. The lesson for the solar industry is that we need strong grassroots support coupled with effective lobbying. Happy net-metered voters are the foot soldiers who will win this war.
2. Nothing definitive will happen with the ITC in 2014, even though extending the ITC is a priority for all segments of the industry. The 30% ITC is the swing factor in states where electric rates and incentives are low. Although the ITC is not required where the economics of solar are already compelling (like HI and CA), there is no other single federal policy that is effective for both customer-owned and third-party-owned systems.
3. Public utility commissions will timidly propose changes to existing utility business models. The irresistible force of cheaper solar technology is stronger than the immovable object of a high guaranteed rate of return for utilities. I use the word "timidly" because utilities have money, political clout and legions of lawyers to effectively lobby to retain their business model.
4. The profitability of investor-owned utilities will begin an inexorable twenty-year decline. Factors such as slower growth in electricity sales, a decline in utility-owned generating capacity, higher borrowing rates, long-term customer uncertainty, inexpensive power substitutes (solar, wind), and the inevitability of cost-effective localized battery storage will apply downward pressure to utilities' stock prices. There is no good news for utilities (except EVs), and it is wishful thinking that they will act altruistically on behalf of DG solar instead of rationally on behalf of their investors.
5. Solar paperwork will get easier in some locations and tougher in others. San Jose, California is a great example of fast, over-the-counter solar permits. And PG&E has implemented procedures so that it can turn around interconnection applications in less than a week. But these victories are generally localized and temporary. Starting in 2014, San Jose will begin enforcing state fire code limits on rooftop solar that eliminate the best 30% of roof area, and PG&E is, after all, an investor-owned utility. Two steps forward, one step backward.
6. Prices for all solar equipment will continue their gradual decline. We are on track to meet GTM's <$0.50/watt module cost target by 2016. Just because it's nice to have consistently profitable solar manufacturers doesn't mean we'll achieve that goal. There will still be companies that will sell at a premium because they are "better" in some way. But since supply is still greater than demand (and supply can be ramped up relatively quickly), price premiums will not be sustainable, as other manufacturers will sell at marginal cost.

7. Customer acquisition costs will stay stubbornly high. Right now, they're on the order of $1/watt when sales-related overhead is included. Lead gen services, better software, and new prospecting tactics are unlikely to make much of a dent in these customer acquisition costs, because there are so many smart and aggressive companies with money to spend on marketing to keep their top line growing. Factors that will eventually reduce these costs are lower incentives, standardized solar equipment, better customer awareness of the costs and benefits, and more people having solar so they can refer their friends (the “diffusion” effect, which has been so successful in Germany).
8. Small solar companies will co-exist with large downstream installers. Little guys won’t go out of business, but they may go into hibernation when the air- and web-waves are blanketed with ads. Small installers will thrive because their overall operating costs are low and their service levels are high. New financing options, including bank loans and credit unions, will make it easier for local installers (as well as electricians, roofers and HVAC contractors) to compete with “no-money-down, free solar” offers.
9. New solar distributors will crop up, and old solar distributors will consolidate. The business of solar distribution will start to streamline when solar installation components become more standardized. We are not there yet; currently, the plethora of products and specifications makes it too difficult for distributors to establish well-stocked local distribution facilities. It is exactly this type of localized product availability that improves supply chain efficiencies for electricians, roofers and other contractors.
10. More focus will be directed toward mundane components like solar roof flashings, grounding, racking, job preparation and supply chains. RMI and Georgia Tech just released a terrific time-and-motion study of rooftop solar installations. Their conclusion: the biggest cost reduction opportunities are with integrated racking, and in eliminating the array of little nuts, bolts, wires, clips, pieces and parts that don’t add any functional value to the system, but still need to be assembled on the rooftop.

II. CONCLUSION

If solar electric power is to become an important source of energy in our future, the industry needs to work together in order to make it affordable for everyone. Lowering costs and increasing the safety and reliability of solar electric power will make it easier for utilities and consumers to select solar power over other forms of energy.

“The Sun has Power – Let’s use it!”

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